

C. Iulios**CAS Reg. No.:**~~9004-34-6~~**Molecular Formula:** $(C_6H_{10}O_5)_n$ **Fragment:** $C_6H_{10}O_5$ **General Info:****Overview of Cellulose - sources and properties.**

Cellulose is a polysaccharide polymer, containing a linear array of anhydroglucose units that are assembled into complex multi-stranded fibres and films. The polymer is the major structural component of plant cell walls and is particularly important in cells that form stems and wood. It is also the major constit. of fibres such as cotton, flax, jute, hemp and ramie. Certain green algae and bacteria also produce the polymer. Chemical processing can rearrange the macromolecular struct. of the polymer, producing fibres such as rayon.

The struct. and props. of cellulose can be described at several levels

The single polymer chain.

The arrays of multiple overlapping chains of the polymer that make elementary fibrils and microfibrils, the basic building blocks found in natural cellulose-containing structs.

Assemblies of microfibrils that combine to make fibrils, the intermediate building blocks in construction of components of plants, such as the framework for cell walls, the skeletons of complex structs. such as stems, wood etc. and valuable fibres such as cotton.

Reconstituted fibres produced commercially by re-precipitating cellulose polymer chains after solubilisation as salts of derivs.

Cellulose**Synonym:****Natural cellulose** **α -Cellulose****Cellulon****Monomers: Related Polymers:****Cellulose II****Cellulose****Material Class****Polysaccharides****Polymer Type:****cellulosics****CAS Reg. No.:**~~9004-34-6~~**Molecular Formula:** $(C_6H_{10}O_5)_n$ **Fragment:** $C_6H_{10}O_5$ **Base monomer unit glucose Mol. Weight:**

MW 331100 (cotton), 366100 (softwood), 339700 (hardwood). DP (of crystalline regions): 200-250 (purified cotton), 300-350 (ramie), 250-400 (unbleached sulfite wood pulp), 2000 (cotton). DP of whole fibres: 2000-14000 (cotton fibre), 9550 (bast fibres), 26500 (Valonia), 2000-3700 (A. xylinum), 8200-8450 (wood)

Additives:**Flame retardants****Morphology:**

Degree of crystallinity: cotton 82-87% (acid hydrol.), 70% (X-ray), 60% (density), 60% (deuterium exchange), 72% (formylation); Ramie 95% (acid hydrol.), 70% (X-ray), 60% (density); wood pulp 65% (X-ray), 65% (density), 45-50% (deuterium exchange), 53-65% (formylation).

A struct. based on a modified two-phase (crystalline-amorph.) model has been reported [27]

Gen ral Info:

Two different forms of crystalline Cellulose I named 1α and 1β have been recognised recently. The 1α form can be converted to 1β at high temps. in alkali. The 1β form is thought to predominate in most fibre and wood celluloses of commercial importance. Main component of higher plant cell walls. Also found in some bacteria, algae, fungi and tunicates. Secondary cell walls of fibres such as cotton are >90% cellulose, while in bast fibres it is ca.. 70% and in woods the content is ca. 40-50%. Cellulose is the most abundant, continually synthesised chemical on earth, wth ca. 8×10^{10} t/yr produced and degraded. Pulping and processing gives the rearranged polymer, Cellulose II (Cellulose II). Crystalline average length: 144 nm (cotton), 120 nm (ramie), 153 nm (wood); width: 50 nm (cotton), 35 nm (ramie), 37 nm (wood); thickness 64 nm (cotton), 40 nm (ramie), 45 nm (wood)

~~~~~**Ethylcellulose**~~~~~

**Synonym:**

Perethylcellulose

**Monomer:**

Base monomer unit glucose

**Related Polymers:**

Cellulose II

**Material Class**

Polysaccharides

**Polymer Type:**

cellulosics

**CAS Reg. No.:**

~~204-92-2~~

**General Info:**

Approx 2.3 ethyl groups per monomer for films; 2.4-25 for lacquer.

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**Cellulose I****Synonym:**

Natural cellulose  
 $\alpha$ -Cellulose  
Cellulon

**Monomers:**

Base monomer unit glucose

**Related Polymers:**

Cellulose II  
Cellulose

**Material Class**

Polysaccharides

**Polymer Type:**

cellulosics

**CAS Reg. No.:**

~~202-91-2~~

**Molecular Formula:**

$(C_6H_{10}O_5)_n$

**Fragment:**

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**Mol. Weight:**

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**Additives:**

Flame retardants

**Morphology:**

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A struct. based on a modified two-phase (crystalline-amorph.) model has been reported [27]

**General Info:**

Two different forms of crystalline Cellulose I named  $1\alpha$  and  $1\beta$  have been recognised recently. The  $1\alpha$  form can be converted to  $1\beta$  at high temps. in alkali. The  $1\beta$  form is thought to predominate in most fibre and wood celluloses of commercial importance. Main component of higher plant cell walls. Also found in some bacteria, algae, fungi and tunicates. Secondary cell walls of fibres such as cotton are >80% cellulose, while in bast fibres it is ca.. 70% and in woods the content is ca. 40-50%. Cellulose is the most abundant, continually synthesised chemical on earth, wth ca.  $8 \times 10^{10}$  t/yr produced and degraded. Pulping and processing gives the rearranged polymer, Cellulose II (Cellulose II). Crystalline average length: 144 nm (cotton), 120 nm (ramie), 153 nm (wood); width: 50 nm (cotton), 35 nm (ramie), 37 nm (wood); thickness 64 nm (cotton), 40 nm (ramie), 45 nm (wood)

### Volumetric and Calorimetric Properties

#### Density:

| No. | Value                           | Note                     |
|-----|---------------------------------|--------------------------|
| 1   | 1.482 – 1.489 g/cm <sup>3</sup> | amorph. x-ray detn. [1]  |
| 2   | 1.535 – 1.547 g/cm <sup>3</sup> | wood pulps [11,22]       |
| 3   | 1.545 – 1.585 g/cm <sup>3</sup> | cotton [11]              |
| 4   | 1.55 g/cm <sup>3</sup>          | ramie [11]               |
| 5   | 1.582 – 1.63 g/cm <sup>3</sup>  | [11]                     |
| 6   | 1.59 – 1.63 g/cm <sup>3</sup>   | crystalline, x-ray detn. |

#### Thermodynamic Props General:

Heat of combustion 17.43 kJ kg<sup>-1</sup> K<sup>1</sup> (cotton) [1,4]. Heat of crystallisation 121.8 kJ kg<sup>-1</sup> [11]

#### Thermal Conductivity:

| No. | Value              | Note                                        |
|-----|--------------------|---------------------------------------------|
| 1   | 0.029 – 0.17 W/m K | papers, various [11]                        |
| 2   | 0.071 W/m K        | cotton, density 0.5 g cm <sup>-3</sup> [11] |

#### Specific Heat Capacity:

| No. | Value                        | Note       |
|-----|------------------------------|------------|
| 1   | 1.214 – 1.357 kJ/(kg °C) [P] | cotton [4] |
| 2   | 1.327 – 1.353 kJ/(kg °C) [P] | hemp [4]   |
| 3   | 1.365 kJ/(kg °C) [P]         | ramie [4]  |

#### Glass Transition Temperature:

| No. | Value       | Note |
|-----|-------------|------|
| 1   | 220 – 245°C | [11] |
| 2   | 243 – 433°C | [11] |

#### Transition Temperatures:

| No. | Value     | Note                            |
|-----|-----------|---------------------------------|
| 1   | 19 – 23°C | Secondary transition temp. [13] |
| 2   | >290°C    | min. Ignition temp. [1]         |
| 3   | 475°C     | Cotton [4]                      |

### Surface Properties and Solubility

#### Solvents/Nonsolvents:

Sol. DMF, chloral, pyridine, [7], conc. mineral acids (with degradation) [1], inorganic salts (e.g. ZnCl<sub>2</sub>, LiCl, Ca(SCN)<sub>2</sub>), strong alkalis, metal complexes (e.g. [Cu(NH<sub>3</sub>)<sub>4</sub>](OH)<sub>2</sub> (Cuoxam), [Cd(en)<sub>2</sub>](OH)<sub>2</sub> (Cadoxen)) [11]. Swollen by: liq. NH<sub>3</sub>, hydrazine [11]. Liq. cryst. with N-methylmorpholine-N-oxide [15]

#### Surface Tension:

| No. | Value        | Note                |
|-----|--------------|---------------------|
| 1   | 36 – 42 mN/m | 20°, wood pulp [17] |

2 42 mN/m 20% cotton [17]

### Transport Properties

#### Water Absorption:

| No. | Value                                                        | Note                                       |
|-----|--------------------------------------------------------------|--------------------------------------------|
| 1   | 0.6 – 11.7% amorph. cellulose, 11-97% relative humidity [16] |                                            |
| 2   | 7 – 8%                                                       | cotton [16]                                |
| 3   | 8 – 14%                                                      | cellulose, 20°, 60% relative humidity [21] |

### Mechanical Properties

#### Mechanical Properties General:

Moduli of rigidity have been reported [6]

#### Tensile Strength at Break:

| No. | Value                            | Note            |
|-----|----------------------------------|-----------------|
| 1   | 200 – 800 MPa [0-13% extension]  | wet, cotton [1] |
| 2   | 200 – 800 MPa [12-16% extension] | dry, cotton [1] |
| 3   | 824 MPa [1.8% extension]         | dry, flax [1]   |
| 4   | 863 MPa [2.2% extension]         | wet, flax [1]   |
| 5   | 900 MPa [(2.3%)]                 | dry, ramie [1]  |
| 6   | 1060 MPa [2.4% extension]        | wet, ramie [1]  |

#### Elastic Moduli:

| No. | Value        | Note      |
|-----|--------------|-----------|
| 1   | 48 – 69 MPa  | ramie [1] |
| 2   | 59 – 78 MPa  | hemp      |
| 3   | 78 – 108 MPa | flax [1]  |

### Electrical Properties

#### Electrical Properties General:

Insulating value 500 kV cm<sup>-1</sup> [10]

#### Strong Field Phenomena General:

Zeta potential 21.1mV (cotton), 18mV (unbleached sulfite pulp, water), 9mV (unbleached sulfite pulp, 20°, water) [11]

#### Dielectric Strength:

| No. | Value           | Note                        |
|-----|-----------------|-----------------------------|
| 1   | 7.7 – 9.2 kV/mm | 50Hz, insulating paper [11] |
| 2   | 30 – 50 kV/mm   | 50Hz, cellophane [4]        |
| 3   | 50 kV/mm        | Native cellulose fibre [11] |

#### Dielectric/Permittivity Constant:

| No. | Value         | Note                    |
|-----|---------------|-------------------------|
| 1   | 1.67 [10 kHz] | 25°, cotton linters [4] |

|   |                |                           |
|---|----------------|---------------------------|
| 2 | 2.2 – 2.3      | pulp sheets [1]           |
| 3 | 2.42 [10 MHz]  | 25°, cotton cellulose [4] |
| 4 | 2.86 [200 kHz] | 25°, cotton cellulose [4] |
| 5 | 5.7            | crystalline portions [1]  |

**Dissipation Factor:**

| No. | Value          | Note     |
|-----|----------------|----------|
| 1   | 0.02 [1 kHz]   | 20° [11] |
| 2   | 0.07 [100 MHz] | 20° [11] |

**Optical Properties****Refractive Index:**

| No. | Value         | Note                                         |
|-----|---------------|----------------------------------------------|
| 1   | 1.525 – 1.534 | perpendicular, ramie [11,14]                 |
| 2   | 1.527 – 1.534 | perpendicular, cotton [11,14]                |
| 3   | 1.544         | perpendicular to fibre axis cellulose I [11] |
| 4   | 1.576 – 1.595 | parallel, cotton [11,14]                     |
| 5   | 1.595 – 1.601 | parallel, ramie                              |
| 6   | 1.618         | parallel to fibre axis, cellulose I [11]     |

**Stability****Polymer Stability General:****Thermal Stability General:**

Decomposition temp. 200-270° [11], 150° (cotton) [12]

**Decomposition Details:**Decomposes at 250-397° giving H<sub>2</sub>O, CO<sub>2</sub>, CO and tar. Major tar component is laevoglucosan [9]**Flammability:**

Fl. p. 361° (cotton) [4]. Limiting Oxygen Index 18.4 % [11]. Mechanism of pyrolysis and the use of flame retardants have been reported [28]

**Biological Stability:**Degraded by cellulases prod. by bacteria such as *Trichoderma* sp.**Hydrolytic Stability:**Susceptible to acid hydroly., with amorph. regions reacting faster than crystalline sections. In alkali the polymer dissolves at elevated temps. undergoing depolymerisation by  $\beta$ -elimination of H<sub>2</sub>O**Applications/Commercial Products****Applications:**

Wide range of uses from cloth to paper, yarn to insulation, and, in the form of wood, as fuel and structural materials

**Tradenames:**

**Tradenames:**

| Grade    | Manufacturer/Supplier |
|----------|-----------------------|
| Cellulon | Bacterial cellulose   |
| Cotton   |                       |
| Hemp     |                       |
| Ramie    |                       |

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**Ethylcellulose****Synonym:**

Perethylcellulose

**Monomers:**

Base monomer unit glucose

**Related Polymers:**

Cellulose II

**Material Class**

Polysaccharides

**Polymer Type:**

cellulosics

**CAS Reg. No.:**

9004-57-3

**General Info:**

Approx 2.3 ethyl groups per monomer for films; 2.4-25 for lacquer.

**Volumetric and Calorimetric Properties****Density:**

| No. | Value                         | Note  |
|-----|-------------------------------|-------|
| 1   | 1.09 - 1.17 g/cm <sup>3</sup> | [6]   |
| 2   | 1.14 g/cm <sup>3</sup>        | [1,3] |

**Thermal Expansion Coefficient:**

| No. | Value                           | Note  |
|-----|---------------------------------|-------|
| 1   | 0.0001 - 0.0002 K <sup>-1</sup> | [1,6] |

**Thermal Conductivity:**

| No. | Value            | Note |
|-----|------------------|------|
| 1   | 0.16 - 0.3 W/m K | [6]  |

**Melting Temperature:**

| No. | Value | Note            |
|-----|-------|-----------------|
| 1   | 135°C | crystalline [6] |

**Glass Transition Temperature:**

| No. | Value | Note    |
|-----|-------|---------|
| 1   | 316°C | [11,13] |

**Deflection Temperatures:**

| No. | Value     | Note         |
|-----|-----------|--------------|
| 1   | 45 - 88°C | 1.82 MPa [6] |

**Vicat Softening Point:**

| No. | Value             | Note |
|-----|-------------------|------|
| 1   | 152 – 162°C [1,3] |      |

**Surface Properties and Solubility****Solubility Properties General:**

Solubility 4-8% NaOH 0.5-0.7 [4]. Cold water 0.8-1.3 [4]. Organic solvents 2.3-2.6 [4]

**Solvents/Nonsolvents:**Liq. crystals sol. CHCl<sub>3</sub> [9], dioxan [11], AcOH [10], DMSO [8]**Surface Tension:**

| No. | Value                          | Note |
|-----|--------------------------------|------|
| 1   | 32 mN/m <sup>20°</sup> [11,12] |      |

**Transport Properties****Polymer Solutions Dilute:**Intrinsic viscosity 11.0 dl g<sup>-1</sup> (MW 625000, DP 2650); 7.75 dl g<sup>-1</sup> (MW 335000, DP 1420); 3.95 dl g<sup>-1</sup> (MW 190000, DP 805) [5]**Water Absorption:**

| No. | Value              | Note |
|-----|--------------------|------|
| 1   | 0.8 – 1.8% 24h [6] |      |
| 2   | 2%                 | [1]  |

**Gas Permeability:**

| No. | Value                                                              | Note                                                                   |
|-----|--------------------------------------------------------------------|------------------------------------------------------------------------|
| 1   | 0.06675 cm <sup>3</sup> /m <sup>2</sup> atm day [H <sub>2</sub> O] | 890 g m <sup>-2</sup> day <sup>-1</sup> , 75 µm film, ASTM E96-66 [1]  |
| 2   | 1740 cm <sup>3</sup> /m <sup>2</sup> atm day [O <sub>2</sub> ]     | 26.5 • 10 <sup>-10</sup> , 30°                                         |
| 3   | 2692 cm <sup>3</sup> /m <sup>2</sup> atm day [CO <sub>2</sub> ]    | 41.0 • 10 <sup>-10</sup> cm <sup>2</sup> (s cmHg) <sup>-1</sup> , 30°  |
| 4   | 5516 cm <sup>3</sup> /m <sup>2</sup> atm day [N <sub>2</sub> ]     | 84 • 10 <sup>-10</sup> , 30°                                           |
| 5   | 5713 cm <sup>3</sup> /m <sup>2</sup> atm day [H <sub>2</sub> ]     | 87 • 10 <sup>-10</sup> cm <sup>2</sup> (s cmHg) <sup>-1</sup> , 20°    |
| 6   | 13396 cm <sup>3</sup> /m <sup>2</sup> atm day [SO <sub>2</sub> ]   | 204 • 10 <sup>-10</sup> cm <sup>2</sup> (s cmHg) <sup>-1</sup>         |
| 7   | 26266 cm <sup>3</sup> /m <sup>2</sup> atm day [He]                 | 400 • 10 <sup>-10</sup> cm <sup>2</sup> (s cmHg) <sup>-1</sup> , 30°   |
| 8   | 27580 cm <sup>3</sup> /m <sup>2</sup> atm day [Ethylene oxide]     | 420 • 10 <sup>-10</sup> cm <sup>2</sup> (s cmHg) <sup>-1</sup> , 0°    |
| 9   | 46294 cm <sup>3</sup> /m <sup>2</sup> atm day [NH <sub>3</sub> ]   | 705 • 10 <sup>-10</sup> cm <sup>2</sup> (s cmHg) <sup>-1</sup> [6]     |
| 10  | 787992 cm <sup>3</sup> /m <sup>2</sup> atm day [H <sub>2</sub> O]  | 12000 • 10 <sup>-10</sup> cm <sup>2</sup> (s cmHg) <sup>-1</sup> , 20° |

**Mechanical Properties****Tensile Strength at Break:**

| No. | Value                           | Note |
|-----|---------------------------------|------|
| 1   | 46 – 72 MPa/dry, 75 µm film [2] |      |

**Mechanical Properties Miscellaneous:**

Wet tensile strength is 80-85% of dry film value [1,3]. Flexibility, folding endurance 160-2000 (dry, 75  $\mu\text{m}$  film) [1,3]

**Hardness:**  
Sward 52-61 (75  $\mu\text{m}$  film) [1,3]. Rockwell R50-R115 [6]

**Izod:**

| No. | Value       | Note    |
|-----|-------------|---------|
| 1   | 21 J/m [No] | 23° [6] |

**Electrical Properties****Volume Resistivity:**

| No. | Value                        | Note  |
|-----|------------------------------|-------|
| 1   | 0.001 – 0.1 $10^{13}$ ohm cm | [1,3] |

**Dielectric Strength:**

| No. | Value             | Note                                        |
|-----|-------------------|---------------------------------------------|
| 1   | 13.8 – 19.7 kV/mm | [6]                                         |
| 2   | 600 kV/mm         | 1500 V in <sup>1</sup> , ASTM D149-64 [1,3] |

**Dielectric/Permittivity Constant:**

| No. | Value             | Note      |
|-----|-------------------|-----------|
| 1   | 2.5 – 4 [60 Hz]   | 25° [1,3] |
| 2   | 2.8 – 3.9 [1 MHz] | 25° [1,3] |
| 3   | 3 – 4.1 [1 kHz]   | 25° [1,3] |

**Dissipation Factor:**

| No. | Value                | Note      |
|-----|----------------------|-----------|
| 1   | 0.002 – 0.02 [1 kHz] | 25° [1,3] |
| 2   | 0.005 – 0.02 [60 Hz] | 25° [1,3] |

**Optical Properties****Refractive Index:**

| No. | Value | Note          |
|-----|-------|---------------|
| 1   | 1.47  | cast film [2] |

**Volume Properties/Surface Properties:**

Light transmission at 310-400 nm is practically complete [1,3] and at 280-310 nm it is <50% complete [1,3]. Discoloration by sunlight is very slight [1,3]

**Stability****Polymer Stability General:****Decomposition Details:**

Decomposes at 306°. Products mainly gases; other products include acetaldehyde, aliphatic

comp unds and furans

### Applications/Commercial Products

#### Proc/Manuf Routes:

Reaction of alkali cellulose with ethyl chloride at high pressure and temp.

#### Applications:

Lacquers and varnishes, printing inks and adhesives. Also used in food and food packaging applications

#### Tradenames:

Tradenames

| Grade | Manufacturer/Supplier |
|-------|-----------------------|
|       | Aqualon               |
|       | Dow                   |

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